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Investigations on Light and Heat, made and published wholly or in part with Appropriation from the Rumford Fund.

XXIII.

CONTRIBUTIONS FROM THE PHYSICAL DEPARTMENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

XVII. — PHOTOGRAPHY OF THE INFRA-RED REGION OF THE SOLAR SPECTRUM.

By William H. Pickering.

Communicated May 14, 1884.

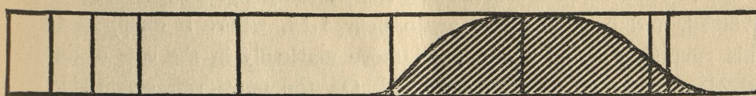
It has been generally assumed, and indeed distinctly stated by Abney and some others, that the gelatine dry plate is insensitive to that region of the spectrum lying beyond A. On trial, however, this proved not to be the case, as the following results distinctly show. It was found that there was a great difference in the plates, those made by Allen and Rowell, and those by Walker, Reid, and Inglis, giving the best results, the latter being somewhat better than the former. This result was indicated by experiments on the sensitiveness of the plates to daylight and gas-light, — the two above-mentioned kinds being the most sensitive of all to the latter, while only moderately so to the former light. The object of the research was to determine to how great a wave-length the plates were sensitive, rather than to obtain a good representation of the lines. A very broad slit was therefore used, and a camera lens of large diameter and short focus. The condensing lens, collimator, and camera lens were each 10 cm. in diameter, and the last of 30 cm. focus. The first two lenses were each of about 90 cm. focal length. The prism measured 10 cm. on a side, and had a refracting angle of 30°. It was so placed that the rays struck the first surface at a slightly oblique angle, thereby obtaining a dispersion equal to that which would be had ordinarily with a 60° prism, and employing only half the thickness of glass. The camera lens had an angular aperture of 19°, and the slit, as usually used, of 1′ 20″. It should be stated here, however, that in the earlier experiments, made with a common spectroscope, using the object-glass of the

telescope as a camera lens, results were obtained which compared very favorably with those reached with the larger instrument. The prism was composed of dense yellow flint glass, and experiments with specimens of ordinary flint and crown glass 7 cm. in thickness gave no more absorption in the infra-red spectrum, as far as observed, than they would in the visible portion; which is entirely contrary to the general belief. An absorptive medium was placed in front of the slit, in order to destroy all light save that of the wave length which it was desired to photograph. This precaution is necessary, as, owing to the reflections from the surfaces of the lenses and prism, a certain amount of diffused light finds its way to the plate, together with the spectrum, and should this diffused light be of short wave-length, it would fog the plate and the spectrum image would be destroyed. It is also necessary to coat the back of the plate with black varnish, in order to prevent the formation of a halo, owing to reflections from the back of the plate. The absorptive medium consisted either of two pieces of red copper glass, or of a piece of red and a piece of blue glass, or of a thin layer of asphalt varnish on glass, of such density as to be slightly lighter than the combined red and blue glass. These all gave about equally good results, with possibly a slight advantage in favor of the asphalt. Other media were experimented upon, including red glass (single, triple, and quadruple), iodine dissolved in carbon bisulphide, lampblack, and hard rubber.

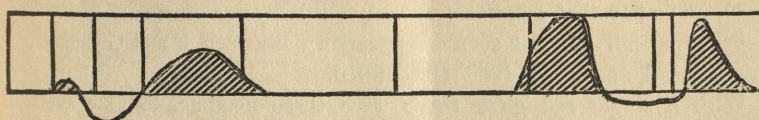
The iodine solution (see diagram) transmitted a large quantity of light in the vicinity of the H lines, — so much, in fact, as to reverse the spectrum in that region. The lampblack showed a slight broad absorption band between F and G, with a maximum at G. Otherwise the spectrum was quite uniform between A and H, and faded away at the two ends, disappearing at wave-lengths .37 and .94 micron. If one wished for a photograph of the visible spectrum only, it would seem as if it might be obtained very satisfactorily by merely inserting a piece of smoked glass in front of the slit. The glass should be smoked until it is about as dark as two pieces of ordinary red and blue glass placed together appear when viewed by transmitted light.

The hard rubber spectrum was obtained with a piece of rubber about .025 cm. in thickness. One could readily see the sun through it, and by close examination detect the window bars when no light came over the shoulder. In structure it was not transparent, but translucent like porcelain, and filled with little irregularities, consisting of short, narrow, opaque lines, lying in the direction in which the sheet had been rolled. On placing it in front of the slit, its spec-

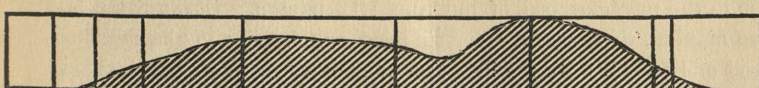
1.38 1.12 .94 A D F G H



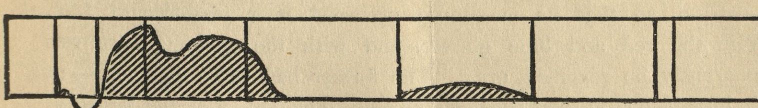
No Medium Interposed.



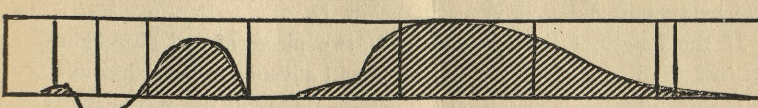
Iodine in Carbon Disulphide.



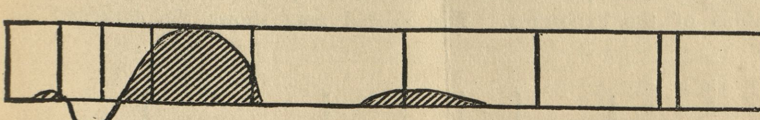
Lampblack.



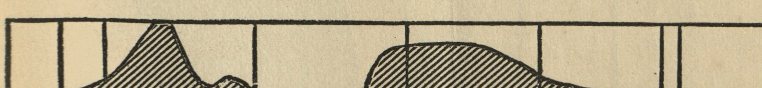
Hard Rubber.



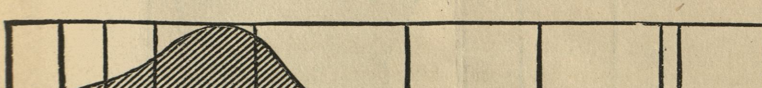
Red Glass.



Red Glass (double).



Red and Blue Glass.



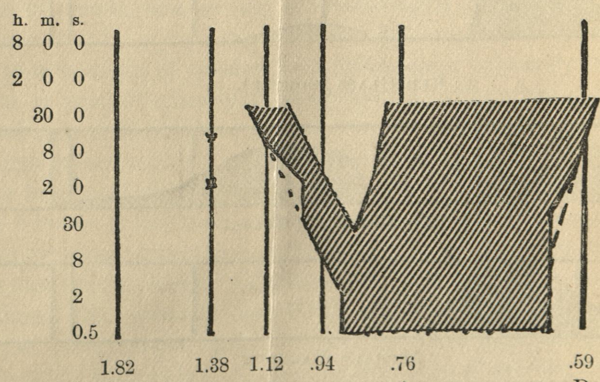
Asphalt Varnish.

1.38 1.12 .94 A D F G H

trum showed a maximum photographic intensity in the neighborhood of the A line, whence it gradually faded away to line .94, where it reversed, and became direct again near 1.12, where it disappeared. This reversing action was noticed more markedly in the case of the red glass, to be presently described. On the more refrangible side of the A line there was a faint absorption band extending half-way to D, and after that a uniform spectrum till D was reached. Here it began to fall off, and soon disappeared. Between F and G there was a small amount of light transmitted.

With a single red glass there were three maxima, the largest between F and G, the next in size between A and D, and a small one in the neighborhood of the line 1.12 micron. Between the last two maxima there was a reversed band culminating in the neighborhood of line .94. By the insertion of another red glass the maximum between F and G was reduced to a small band in the vicinity of F, and the reversed area was transferred somewhat lower down in the spectrum, so that its maximum occurred near wave-length 1.04. With the red and blue glasses, and with the asphalt, there was apparently no reversed area. The former had three maxima, — at F, just below D, and just above A. The last was the strongest marked, and the one near D was very small. The asphalt had only one maximum, and that was just below D.

If the length of the exposure with two pieces of red glass be increased, the limits of the reversed area will advance in both directions, as is shown by the figure, where abscissas represent the wave-lengths in the prismatic spectrum, and ordinates are proportional to the logarithms of the exposures. The shaded area shows the darkened



portion of the spectrum, while the deep notch represents the reversed portion. This series of exposures was taken on a fairly clear day, but occasionally wave-length 1.38 has been reached in from two to ten minutes, as is shown by the two crosses on the left.

There was a great difference in the transparency of the atmosphere noted on different days. This was noticed by Abney. Strangely enough, quite as good results have been obtained in December as in May and June.

The A line is one of the easiest in the spectrum to photograph, and with the slit $5'$ in breadth, it may be taken in one half-second. If the slit is $1'\ 20''$ wide, the spectrum may any day be photographed as far as wave-length 1.00 in two minutes, and under favorable circumstances as far as 1.38, but beyond that it is not easy to obtain satisfactory results.